APPENDIX E

Blackleaf EIS Area Reserves: Methodology and Calculations

This appendix describes the method used to determine the total reserves in the EIS area, and contains calculation and tables of reserve estimates for each well proposed in each alternative.

Background for calculating the reserves in the Blackleaf EIS area.

Sections were rated high, medium, or low based on the following definitions:

Low (L) - Either previously explored or no drilling application is expected.

Medium (M) - Hasn't been drilled; is near structure.

High (H)- Drilling has been proposed at one time or another or it appears to be a logical place based on geology to test the extent of a structure; previous drilling yielded significant shows.

Geologic maps and cross sections from several sources including the Montana Geologic Society (MGS) Bulletin, 1985, and Williams Exploration Company were used in the geologic evaluations. Figures 1 and 2 at the end of this appendix are structure contour maps developed using this information.

Reservoir Values:

From the MGS Bulletin, 1985 were used to determine the high value for potential reserves (350 feet of pay and 167 MCF of gas per acre/foot).

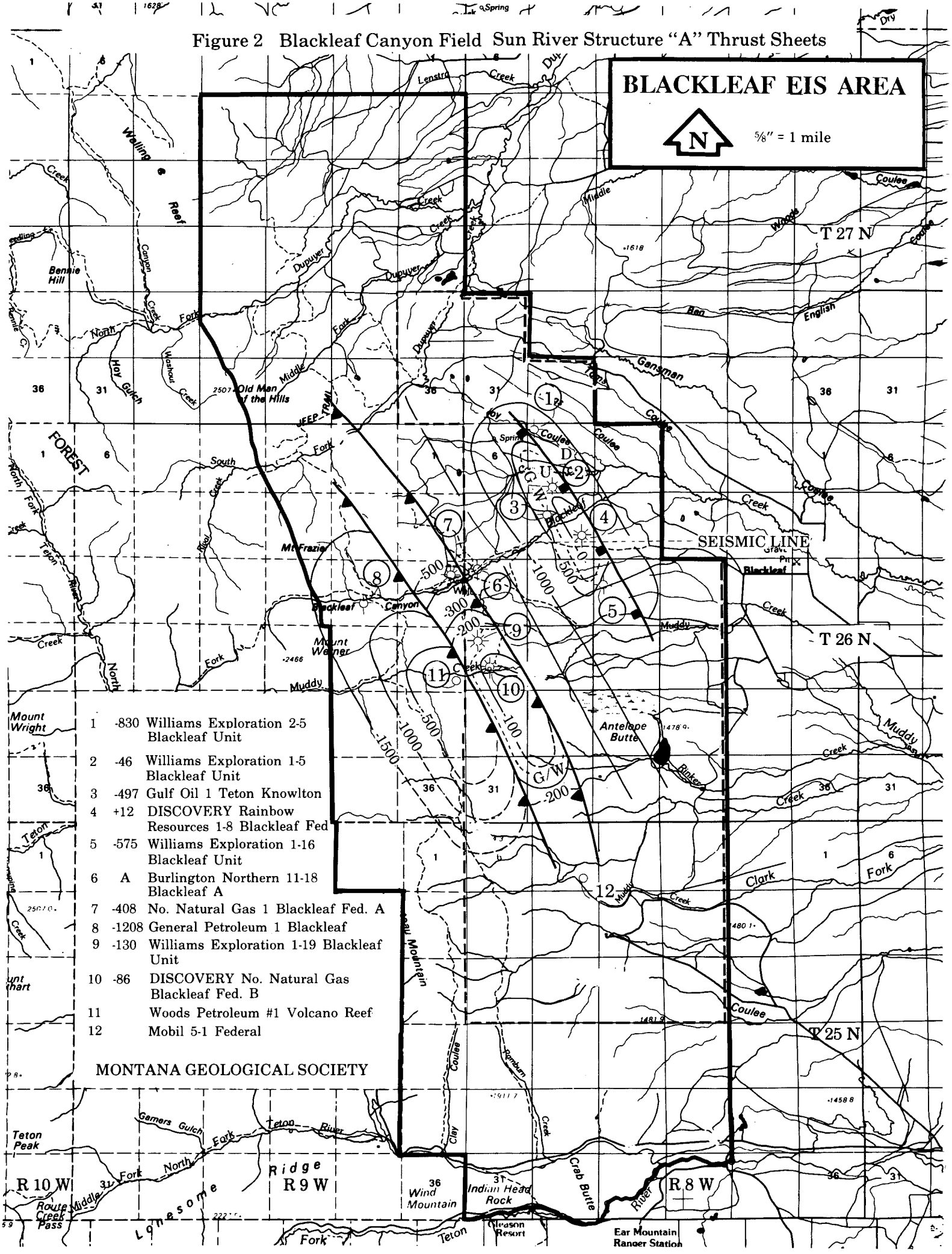
Superior Oil figures were used to calculate the low value for potential reserves (350 feet of pay and 65 MCF of gas per acre/foot).

For a high section, 30% of the area was estimated to have recoverable reserves.

For a medium section, 15% of the area was estimated to have recoverable reserves.

For a low section, 10% of the area was estimated to have

Figure 2 Blackleaf Canyon Field Sun River Structure "A" Thrust Sheets



1	-830	Williams Exploration 2-5 Blackleaf Unit
2	-46	Williams Exploration 1-5 Blackleaf Unit
3	-497	Gulf Oil 1 Teton Knowlton
4	+12	DISCOVERY Rainbow Resources 1-8 Blackleaf Fed
5	-575	Williams Exploration 1-16 Blackleaf Unit
6	A	Burlington Northern 11-18 Blackleaf A
7	-408	No. Natural Gas 1 Blackleaf Fed. A
8	-1208	General Petroleum 1 Blackleaf
9	-130	Williams Exploration 1-19 Blackleaf Unit
10	-86	DISCOVERY No. Natural Gas Blackleaf Fed. B
11		Woods Petroleum #1 Volcano Reef
12		Mobil 5-1 Federal

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recoverable reserves.

Each section was considered to be 640 acres in size.

Table 1 lists the classification of each section within the EIS boundary.

Section	Township	Range	Status	
9	27N	9W	M -	along the west edge of a surface fault
10	27N	9W	L -	east of fault line and no interest shown in this area by companies that th agencies are aware of
11	27N	9W	L -	east of a fault line and no interest shown in this area by companies that th agencies area aware of
12	27N	9W	M -	near a fault line
13	27N	9W	M -	near a fault line
14	27N	9W	L -	between two faults
15	27N	9W	M -	west of a fault line and covers part of a surface fault
16	27N	9W	L -	(M) trend of structure is possibly NW-SE
21	27N	9W	L -	(M) trend of structure is possibly NW-SE
22	27N	9W	M -	is on trend of general structure, is on a fold
23	27N	9W	L -	dry hold has been drilled
24	27N	9W	L -	based on cross section, there doesn't appear to have any subsurface faulting t produce traps
25	27N	9W	L -	based on cross section, there doesn't appear to have any subsurface faulting t produce traps
26	27N	9W	H -	on a fold-gas shows in both wells drilled in section
27	27N	9W	H -	on a fold
28	27N	9W	L -	appears to be on the end of a structure
33	27N	9W	L -	structural complexity
34	27N	9W	M -	possibly higher on structure
35	27N	9W	H -	on a fold, possibly high on structure
36	27N	9W	M -	near a fault line
30	27N	8W	M -	associated with a fault
31	27N	8W	L -	fault north of dry hole in Section 5
32	27N	8W	L -	see above, also outside of thrust belt
4	26N	8W	L -	outside of thrust belt
5	26N	8W	L -	has a producing well and one dry hole
6	26N	8W	L -	not associated with a structure
7	26N	8W	L -	not associated with a structure
8	26N	8W	L -	producing gas well in this section
9	26N	8W	L -	outside thrust belt
15	26N	8W	L -	outside thrust belt
16	26N	8W	L -	temporarily abandoned gas well in this section
17	26N	8W	L -	not associated with structure
18	26N	8W	L -	dry hole
19	26N	8W	L -	shut-in gas well
20	26N	8W	L -	not associated with a structure
21	26N	8W	H -	possible structure
22	26N	8W	L -	outside thrust belt
27	26N	8W	L -	not associated with a structure
28	26N	8W	M -	associated with a structure
29	26N	8W	M -	associated with a structure
30	26N	8W	H -	well proposed in past appears to be on structural trend
31	26N	8W	M -	possible structure
32	26N	8W	H -	possible high on structure
33	26N	8W	M -	possible structure
34	26N	8W	L -	not associated with a structure
1	26N	9W	H -	apparently on structure with 1-13 well
2	26N	9W	H -	apparently on structure with 1-13 well
3	26N	9W	L -	off structure
10	26N	9W	L -	off structure, complex
11	26N	9W	H -	drilling proposed in past
12	26N	9W	H -	on structure
13	26N	9W	L -	shut-in gas well
14	26N	9W	L -	plugged and abandoned off structure
15	26N	9W	L -	off structure
23	26N	9W	L -	off structure

24	26N	9W	H -	drilling proposed, permit expired
25	26N	9W	M -	on structure
26	26N	9W	L -	off structure
35	26N	9W	L -	off structure
36	26N	9W	L -	off structure
3	25N	8W	L -	near edge of thrust belt
4	25N	8W	M -	on possible structure
5	25N	8W	L -	plugged and abandoned well
6	25N	8W	M -	on structure, higher than 5 above
7	25N	8W	M -	on structure
8	25N	8W	L -	off structure
9	25N	8W	M -	on structure
10	25N	8W	L -	apparently not associated with structure, dry hole to north
15	25N	8W	L -	apparently not associated with structure, dry hole to north
16	25N	8W	M -	apparently on structure
17	25N	8W	M -	apparently on structure
18	25N	8W	M -	apparently on structure
19	25N	8W	L -	off structure
20	25N	8W	M -	on structure
21	25N	8W	L -	plugged and abandoned well
22	25N	8W	L -	apparently no structure
27	25N	8W	L -	plugged and abandoned well
28	25N	8W	M -	on structure
29	25N	8W	M -	on structure
30	25N	8W	L -	off structure
31	25N	8W	L -	off structure
32	25N	8W	M -	on structure
33	25N	8W	M -	on structure
1	25N	9W	L -	off structure
2	25N	9W	L -	Subbelt II, complex
12	25N	9W	L -	off structure & getting into Subbelt II
13	25N	9W	L -	off structure
24	25N	9W	L -	off structure
25	25N	9W	L -	off structure

In total there are 11 high potential sections, 25 medium potential, and 53 low potential sections. This equates to 7,040 acres of high potential, 16,000 acres of medium potential and 33,920 acres of low potential.

Productive Acres

7,040 x 30% = 2,112 productive acres
16,000 x 15% = 2,400 productive acres
33,920 x 1% = 339.2 productive acres
Total 4,851.2 productive acres

Low Reserve Estimate

4,851.2 acres x 65 MCF/acre-foot x 350 feet = 110,364,800 MCF or approx. 110 BCF

High Reserve Estimate

4,851.2 acres x 167 MCF/acre-foot x 350 feet = 283,552,640 MCF or approx. 284 BCF

To calculate the actual production from each well proposed under the different alternatives, actual production figures, declines and initial production values were used.

For 1-5 actual production: 100,000 MCF/month (65% IP)
IP=153,000 MCF/month
actual decline 1% month

For 1-8 actual production: 112,000 MCF/month (40%IP) IP=270,000 MCF/month
actual decline 2% month

For high production scenario assume 1%/month decline rate
For low production scenario assume 2%/month decline rate

Assume actual initial production is 50% of tested IP
Assume abandonment rate of 3000 MCF/month

For 1-13 Use the average IP of the two wells drilled in Section 13
#1 in 1958-IP 6.297 MMCF
#1-13 in 1981-IP 1.400 MMCF
average = 3850 MCF/day =115,500 MCF/month
assume 50% for actual production
115,500 X .5 = 57,500 MCF/month

For 1-19 Use IP of 4.074 MMCF/day
4074 MCF/Day = 122,000 MCF/month
assume actual production equals 50% of IP
122,000 X .5 = 61,000 MCF/month

For B-1 Use average IP of the two wells drilled in Section 19. The B-1 969 MCF/day and the 1-19 4074 MCF/day. The average = 75,600 MCF/month
Assume actual production equals 50% of IP
75,600 X .5 = 37,800 MCF/month

The above assumptions and production values and the following formulas were; used to calculate the High and Low production estimates and the well lives for the 1-5, 1-8, 1-13, 1-19, and B-1 wells listed in Table E-1.

$$Gp = \frac{12(qi - qf)}{D}$$

$$T = \frac{\ln(qi/qf)}{D}$$

Where qi= actual initial monthly production
qf= abandonment rate (3000mcf/month)
D = Decline rate per year
T = Productive life in years
ln= the natural logarithm

1-5 High

$$\frac{12(100{,}000-3000)}{.12} = Gp = 9.7 \text{ BCF}$$

$$\frac{\ln(100{,}000/3000)}{.12} = T = 29 \text{ years}$$

1-5 Low

$$\frac{12(100{,}000-3000)}{.24} = Gp = 4.9 \text{ BCF}$$

$$\frac{\ln(100{,}000/3000)}{.24} = T = 15 \text{ years}$$

1-8 High

$$\frac{12\ (112{,}000-3000)}{.12} = Gp = 10.9 \text{ BCF}$$

$$\frac{\ln(112{,}000/3000)}{.12} = T = 30 \text{ years}$$

1-8 Low

$$\frac{12\ 112{,}000-3000}{.24} = Gp = 5.5 \text{ BCF}$$

$$\frac{\ln(112{,}000/3000)}{.24} = T = 15 \text{ years}$$

1-13 High

$$\frac{12(57500-3000)}{.12} = Gp = 5.5 \text{ BCF}$$

$$\frac{\ln(57500/3000)}{.12} = T = 25 \text{ years}$$

1-13 Low

$$\frac{12(57500-3000)}{.24} = Gp = 2.8 \text{ BCF}$$

$$\frac{\ln(57500/3000)}{.24} = T = 13 \text{ years}$$

1-19 High

$$\frac{12(61000/3000)}{.12} = Gp = 5.8 \text{ BCF}$$

$$\frac{\ln(61000/3000)}{.12} = T = 25 \text{ years}$$

1-19 Low

$$\frac{12(61000-3000)}{.24} = Gp = 2.9 \text{ BCF}$$

$$\frac{\ln(61000/3000)}{.24} = T = 13 \text{ years}$$

B-1 High

$$\frac{12(37{,}800-3000)}{.12} = Gp = 3.5 \text{ BCF}$$

$$\frac{\ln(37{,}800/3000)}{.12} = T = 21 \text{ years}$$

B-1 Low

$$\frac{12(37800-3000)}{.24} = Gp = 1.7 \text{ BCF}$$

$$\frac{\ln(37800/3000)}{.24} = T = 11 \text{ years}$$

Table E-1: Existing Wells High and Low Production Estimates

Well Number	High Production Estimate	Low Production Estimate
1-5	9.7	4.9
1-8	10.9	5.5
1-13	5.5	2.8
1-19	5.8	2.9
B-1*	3.5	1.7

* For these calculations the B-1 was considered existing because a production potential is known.

Site selection for the step-out and exploration wells is based on corporate information, geologic interpretations, topographic constraints, and the project geologist's and engineer's professional opinions.

The estimated high production values for each step-out well is based on a recovery percentage of the estimated drainage area for each well. The drainage area was estimated based on geologic and engineering parameters of the well site. In all cases a net pay of 350 feet, recoverable reserves of 167 MCF per acre foot, and a decline rate of 12% is assumed. Table E-2 lists the various values for each of the step-out wells.

Low reserve estimates for the step out and exploration wells are assumed to be zero for all alternatives.

High reserve calculations for Alternative 2 (least restrictive) form the basis for reserve, initial production, and well life calculations in Alternatives 1, 3, and 4.

Decrease in high production values is based on back pressures caused by increased pipelining distances and cost increases/decreases associated with each alternative.

Tables E-2 through E-9 list the reserve potential for each of the step-out wells proposed for the four alternatives.

Table E-2

High Reserve and Well Life Estimates for Step Out Wells

WELL NUMBER	LOCATION	ESTIMATED ACRES DRAINED[1]	ESTIMATED RESERVES* (BCF) (Based on 58450 MCF/Acre)[2]	ESTIMATED PRODUCIBLE RESERVES (Gp) (MCF) (55-60% of Est. Reserves)	INITIAL PRODUCTION (qi) $qi=\frac{Gp(MCF)*.d+qf}{12}$ DECLINE (d)=12% ECONOMIC LIMIT (qf)=3000MCF/Month	ESTIMATED WELL LI $T=\frac{1N(qi/qf)}{d}$
S-1	21-26N-8W	280	16.1	9,200,000	95,000	29
S-2 (ALT. 2)	32-26N-8W	440	25.8	14,700,000	150,000	33
*S-2 (ALT. 4)	32-26N-8W	550	32.1	19,300,000		
S-3	24-26N-8W	135	7.9	4,500,000	48,000	23
S-4 (ALT. 2)	30-26N-9W	410	24.2	13,800,000	141,000	32
*S-4 (ALT. 4)	19-26N-8W	145	8.5	5,000,000		
S-5	12-26N-8W	240	14.0	8,000,000	83,000	28
S-6	1-26N-9W	300	17.5	10,000,000	103,000	29
S-7	2-26N-9W	140	8.2	4,700,000	50,000	23
S-8	35-26N-9W	160	9.3	5,300,000	56,000	24

1/ Area of drainage estimated based on a radius of drainage, fault interpretation and predicted interference.

2/ Montana Geologic Society Bulletin based on 167MCF/Acre-ft and 350 feet of pay.

* Sites S-2 and S-4 were located differently for Alternative 4.

Table E-3

High Reserve and Well Life Estimates for Alternative 1 Existing Wells

WELL NUMBER	LOCATION	ESTIMATED PRODUCIBLE RESERVES (BCF) BASED CENTRAL PROCESSING FACILITY ON LOCATION ALTERNATIVE 2)	ESTIMATED REDUCTION IN PRODUCTION AMOUNTS BASED ON CENTRAL PROCESSING FACILITIES[1]	HIGH RESERVES ESTIMATE (MCF)	INITIAL PRODUCTION (qi) MCF/MONTH $qi=\frac{Gp(MCF)d+qf}{}$ DECLINE(d)=12% qf=3000MCF/MONTH	ESTIMATED WEL LIFE (YEARS) $T=\frac{ln(qi/qf)}{d}$
1-5	5-26N-8W	9.7	10%	8,700,000	90,000	28
1-8	8-26N-8W	10.9	10%	9,800,000	101,000	29
1-13	13-26N-9W	5.5	25%	4,100,000	44,000	22
1-19	19-26N-8W	5.8	25%	4,400,000	47,000	23

1/ These estimates are based on increased backpressure on well due to pipeline length; increase costs for piping requirements, decrease in cost for decrease in production facilities.

Table E-4
Low Reserve Estimates for Alternatives 1 and 3 Existing Wells 1/

WELL NUMBER	LOCATION	ESTIMATED LOW PRODUCIBLE RESERVES (TABLE 1)(BCF)	ESTIMATED REDUCTION IN PRODUCTION AMOUNTS BASED ON CENTRAL PROCESSING FACILITIES[2]	ALTERNATIVES 1 & 3 LOW RESERVE ESTIMATE (BCF)
1-5	5-26N-8W	4.9	10%	4.4
1-8	8-26N-8W	5.5	10%	5.0
1-13	13-26N-9W	2.8	25%	2.1
1-19	19-26N-8W	2.9	25%	2.2

1/ Low reserves for step-out wells are assumed to be zero.

2/ These estimates are based on increased backpressure on well due to pipeline length; increase costs for piping requirements, decrease in cost for decrease in production facilities.

Table E-5

High Reserve and Well Life Estimates for Alternative 2 Existing Wells 1/
(Production Facilities Located on Well Site)

WELL NUMBER	LOCATION	INITIAL PRODUCTION (qi) MCF/MONTH	ESTIMATED PRODUCIBLE RESERVES (Gp) MCF $qi=\frac{Gp(MCF).d+qf}{12}$ (DECLINE (d)=12% ECONOMIC LIMIT (qf)=3000MCF/MONTH	ESTIMATED WELL LIFE $T=\frac{\ln(qi/qf)}{d}$ qf=3000MCI/MONTH d=12%
1-5	5-26N-8W	100,000	9,700,000	29
1-8	8-26N-8W	112,500	10,790,000	30
1-13	13-26N-9W	57,500	5,500,000	25
1-19	19-26N-8W	61,000	5,800,000	25
B-1	19-26N-8W	37,800	3,500,000	21

1/ Low reserve estimates for Alternative 2 existing wells are found in Table E-1.

Table E-6

High Reserve and Well Life Estimates for Alternative 2 Step Out Wells
(Production Facilities Located on Well Site)

WELL NUMBER	LOCATION	ESTIMATED PRODUCIBLE RESERVES (Gp) MCF	INITIAL PRODUCTION (qi) $qi=\frac{Gp(MCF).d+qf}{12}$ (DECLINE (d)=12% ECONOMIC LIMIT (qf)=3000MCF/MONTH	ESTIMATED WELL LIFE $T=\ln(qi/qf)$
S-1	21-26N-8W	9,200,000	95,000	29
S-2	21-26N-8W	14,700,000	150,000	33
S-3	32-26N-8W	4,500,000	48,000	23
S-4	24-26N-9W	13,800,000	141,000	32
S-5	30-26N-8W	8,000,000	83,000	28
S-6	12-26N-9W	10,000,000	103,000	29
S-7	1-26N-9W	4,700,000	50,000	23
S-8	2-26N-9W	5,300,000	56,000	24

Table E-7

High Reserve and Well Life Estimates for Alternative 3 Existing Wells and Step-out Wells 1/

WELL NUMBER	LOCATION	ESTIMATED PRODUCIBLE RESERVES (BCF) BASED ON PRODUCTION EQUIPMENT ON LOCATION (ALTERNATIVE 2)	ESTIMATED REDUCTION IN PRODUCTION AMOUNTS BASED ON CENTRAL PROCESSING FACILITIES 2/	ALTERNATIVE 3 HIGH RESERVES ESTIMATE (MCF)	INITIAL PRODUCTION (qi) MCF/MONTH $qi=\frac{Gp(MCF)d+qf}{12}$ D=12% qf=300MCXF/MONTH	ESTIMATED LIFE OF WELL $T=\frac{\ln(qi/qf)}{d}$
1-5	5-26N-8W	9.7	10%	8,700,000	90,000	28
1-8	8-26N-8W	10.9	10%	9,800,000	101,000	29
1-13	13-26N-9W	5.5	25%	4,100,000	44,000	22
1-19	19-26N-8W	5.8	25%	4,400,000	47,000	23
S-1	21-26N-8W	9.2	25%	6,900,000	72,000	26
S-2	32-26N-8W	14.7	25%	11,000,000	113,000	30

1/ For Low reserve estimates see Table E-4.

2/ These estimates are based on increased backpressure on well due to pipeline length; increase costs for piping requirements, decrease in cost for decrease in production facilities.

Table E-8

High Reserve and Well Life Estimates for Alternative 4 Existing Wells and Step-out Wells

WELL NUMBER	LOCATION	ESTIMATED PRODUCIBLE RESERVES (BCF) BASED ON PRODUCTION EQUIPMENT ON LOCATION (ALTERNATIVE 2)	ESTIMATED REDUCTION IN PRODUCTION AMOUNTS BASED ON CENTRAL PROCESSING FACILITIES[1]	ALTERNATIVE 3 HIGH RESERVES ESTIMATE (MCF)	INITIAL PRODUCTION (qi) MCF/MONTH $qi=\frac{Gp(MCF)d+qf}{12}$ D=12% qf=300MCXF/MONTH	ESTIMATED LIFE OF WELL $T=\frac{\ln(qi/qf)}{d}$
1-5	5-26N-8W	9.7	10%	8,700,000	90,000	28
1-8	8-26N-8W	10.9	10%	9,800,000	101,000	29
1-13	13-26N-9W	5.5	25%	4,100,000	44,000	22
1-19	19-26N-8W	5.8	25%	4,400,000	47,000	23
B-1	19-26N-8W	3.5	25%	2,600,000	29,000	19
S-1	21-26N-8W	9.2	25%	6,900,000	72,000	26
[2]/S-2	32-26N-8W	19.3*	25%	14,500,000	148,000	32
S-3	24-26N-8W	4.5	25%	3,400,000	37,000	21
[3]/S-4	19-26N-8W	5.0	25%	3,800,000	41,000	22
S-5	12-26N-9W	8.0	25%	6,000,000	63,000	25
S-8	35-26N-9W	5.3	25%	4,000,000	43,000	22

1/ These estimates are based on increased backpressure on well due to pipeline length; increased costs for piping requirements, decreased costs for decrease in production facilities, and increased operating costs for remote monitoring.

2/ Well location has been moved for this alternative resulting in an estimate of greater producible reserves.

3/ Well location has been moved for this alternatiave resulting in an estimate of significantly less producible reserves.

* Estmiated reserves based on 550 acres drained at 58450 MCF/Acre (see Table E-1)

Table E-9

Low Reserve Estimates for Alternative 4 Existing Wells

WELL NUMBER	LOCATION	ESTIMATED PRODUCIBLE RESERVES (BCF) BASED ON PRODUCTION EQUIPMENT ON LOCATION (ALTERNATIVE 2)	ESTIMATED REDUCTION IN PRODUCTION AMOUNTS BASED ON CENTRAL PROCESSING FACILITIES[1]	ALTERNATIVE 4 LOW RESERVES ESTIMATE (BCF)
1-5	5-26N-8W	4.9	10%	4.4
1-8	8-26N-8W	5.5	10%	5.0
1-13	13-26N-9W	2.8	25%	2.1
1-19	19-26N-8W	2.9	25%	2.2
B-1	19-26N-8W	1.7	25%	1.3

1/ These estimates are based on increased backpressure on well due to pipeline length; increase costs for piping requirements, decrease in cost for decrease in production facilities.

Figure 1 Blackleaf Canyon Field Sun River Structure "B" Thrust Sheet